

What Is a Control Chart?

A statistical tool used to distinguish between process variation resulting from common causes and variation resulting from special causes.

Why Use Control Charts?

- Monitor process variation over time
- Differentiate between special cause and common cause variation
- Assess effectiveness of changes
- Communicate process performance

What Are the Control Chart Types?

Chart types studied in this module:

X-Bar and R Chart

Individual X and Moving Range Chart

- *For Variables Data*
- *For Attribute Data*

Other Control Chart types:

X-Bar and S Chart

u Chart

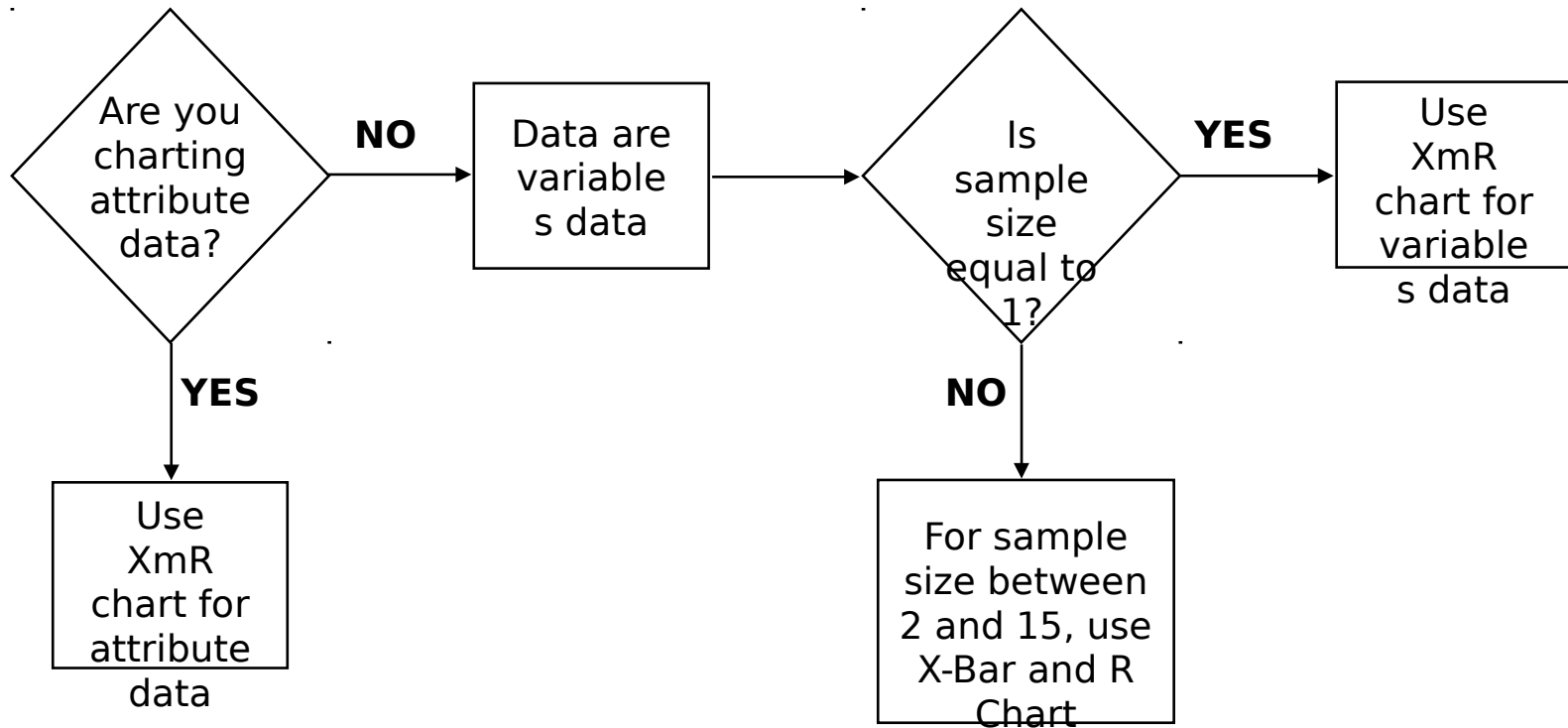
Median X and R Chart

p Chart

c Chart

np Chart

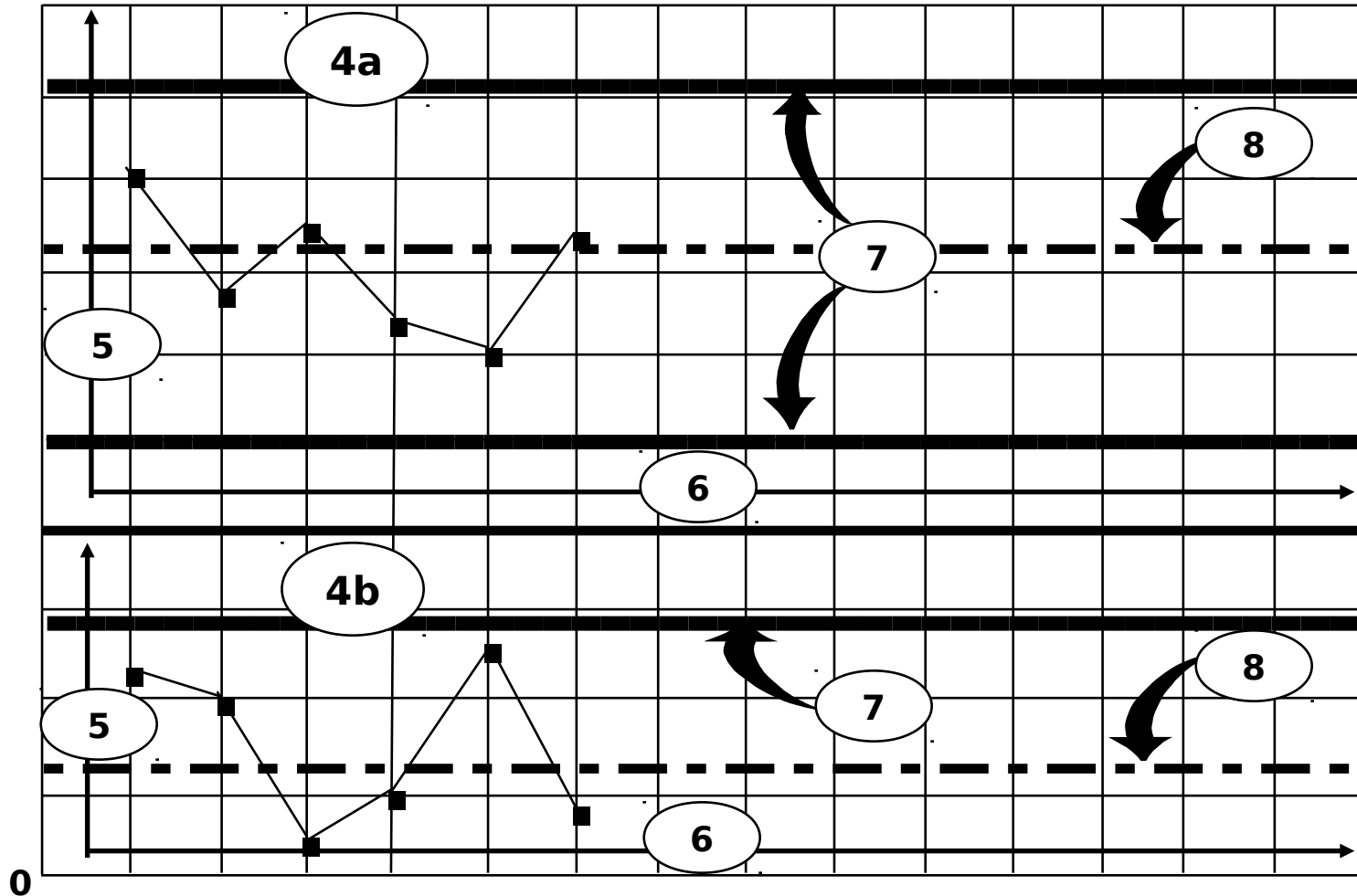
Control Chart Decision Tree



Elements of a Control Chart

Title: <div>1</div>																Legend: <div>2</div>															
Date																															
M E A S U R E M E N T S	1																														
	2					<div>3</div>																									
	3																														
	4																														
	5																														
	6																														
Average																															
Range																															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14																

Elements of a Control Chart



Constructing an X-Bar & R Chart

Step 2 - Collect and enter data by subgroup

Title: _____											Legend: _____				
Date		1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb	8 Feb	9 Feb					
M E A S U R E M E N T S	1	15.3	14.4	15.3	15.0	15.3	14.9	15.6	14.0	14.0					
	2	14.9	15.5	15.1	14.8	16.4	15.3	16.4	15.8	15.2					
	3	15.0	14.8	15.3	16.0	17.2	14.9	15.3	16.4	13.6					
	4	15.2	15.6	18.5	15.6	15.5	16.5	15.3	16.4	15.0					
	5	16.4	14.9	14.9	15.4	15.5	15.1	15.0	15.3	15.0					
Average															
Range															
		1	2	3	4	5	6	7	8	9					
A V E R A G E															

**Enter data by
subgroup in time
sequence**

Constructing an X-Bar & R Chart

Step 3 - Calculate and enter subgroup averages

Title: _____ Legend: _____

Date	1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb	8 Feb	9 Feb					
M E A S U R E M E N T S	1	15.3	14.4	15.3	15.0	15.3	14.9	15.6	14.0	14.0				
	2	14.9	15.5	15.1	14.8	16.4	15.3	16.4	15.8	15.2				
	3	15.0	14.8	15.3	16.0	17.2	14.9	15.3	16.4	13.6				
	4	15.2	15.6	18.5	15.6	15.5	16.5	15.3	16.4	15.0				
	5	16.4	14.9	14.9	15.4	15.5	15.1	15.0	15.3	15.0				
Average	15.36	15.04	15.82	15.36	15.98	15.34	15.52	15.58	14.56					
Range														
	1	2	3	4	5	6	7	8	9					
A V E R A G E														

**Enter the average
for each subgroup**

Title: _____												Legend: _____				
Date		1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb	8 Feb	9 Feb						
M E A S U R E M E N T S	1	15.3	14.4	15.3	15.0	15.3	14.9	15.6	14.0	14.0						
	2	14.9	15.5	15.1	14.8	16.4	15.3	16.4	15.8	15.2						
	3	15.0	14.8	15.3	16.0	17.2	14.9	15.3	16.4	13.6						
	4	15.2	15.6	18.5	15.6	15.5	16.5	15.3	16.4	15.0						
	5	16.4	14.9	14.9	15.4	15.5	15.1	15.0	15.3	15.0						
Average		15.36	15.04	15.82	15.36	15.98	15.34	15.52	15.58	14.56						
Range		1.5	1.2	3.6	1.2	1.9	1.6	1.4	2.4	1.6						
		1	2	3	4	5	6	7	8	9						
A V E R A G E																

**Enter the range for
each subgroup**

Constructing an X-Bar & R Chart

Step 5 - Calculate grand mean

Step 6 - Calculate average of subgroup ranges

Step 7 - Calculate UCL and LCL for subgroup averages

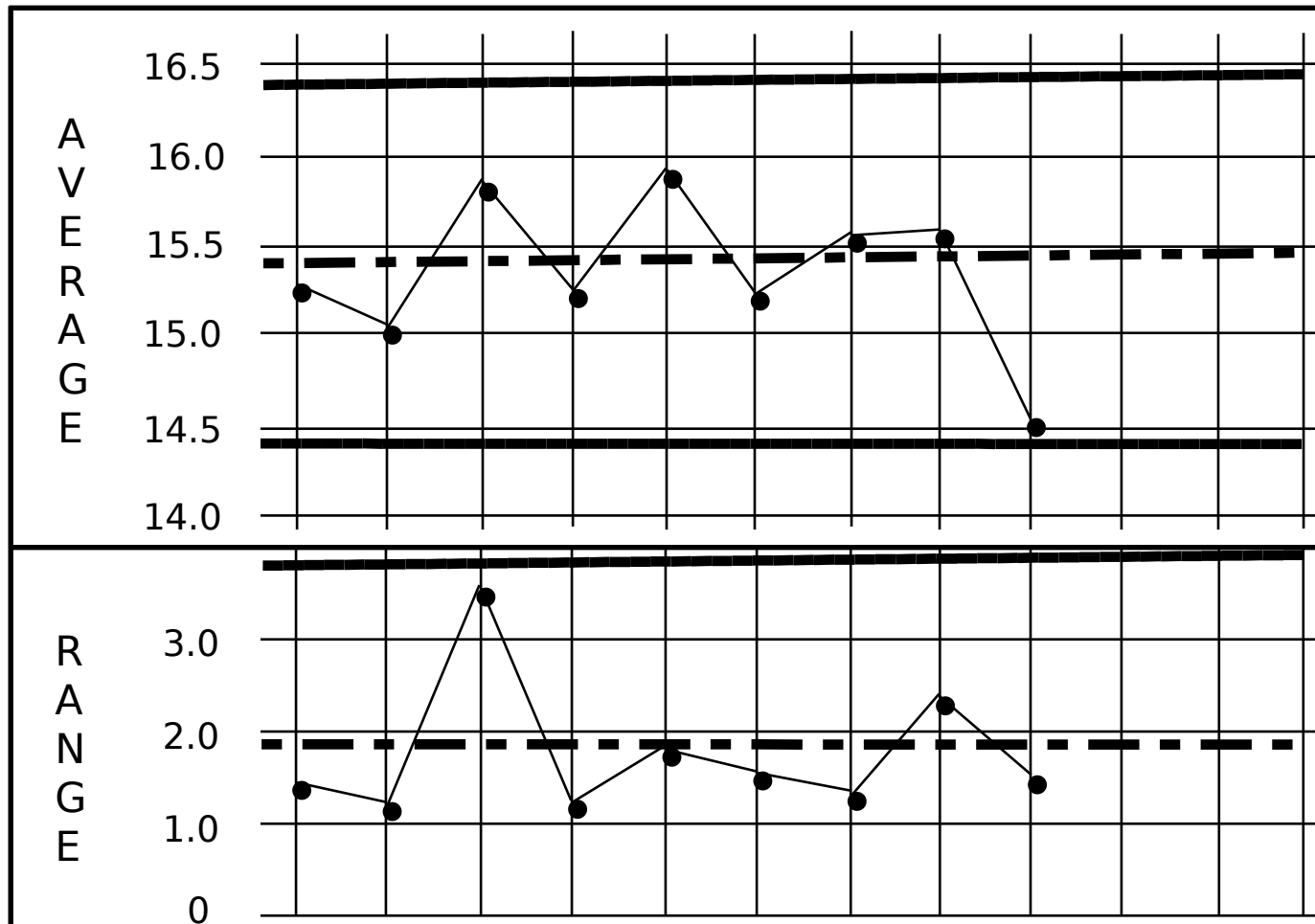
Step 8 - Calculate UCL for ranges

Step 9 - Select scales and plot

Step 10 - Document the chart

Constructing an X-Bar & R Chart

Step 9 - Select scales and plot



Constructing an XmR Chart

Step 2 - Collect and enter individual measurements

Title: _____

Legend: _____

Date	1 Apr	2 Apr	3 Apr	4 Apr	5 Apr	6 Apr	7 Apr	8 Apr	9 Apr	10 Apr		
Individual	19	22	16	18	19	23	18	15	19	18		
\bar{X} Moving R												
	1	2	3	4	5	6	7	8	9	10		
I N D I V I D U A L X												

Enter individual measurements in time sequence

Constructing an XmR Chart

Step 3 - Calculate and enter moving ranges

Title: _____ Legend: _____

Date	1 Apr	2 Apr	3 Apr	4 Apr	5 Apr	6 Apr	7 Apr	8 Apr	9 Apr	10 Apr		
Individual	19	22	16	18	19	23	18	15	19	18		
\bar{X} Moving R		3	6	2	1	4	5	3	4	1		
	1	2	3	4	5	6	7	8	9	10		

INDIVIDUAL X

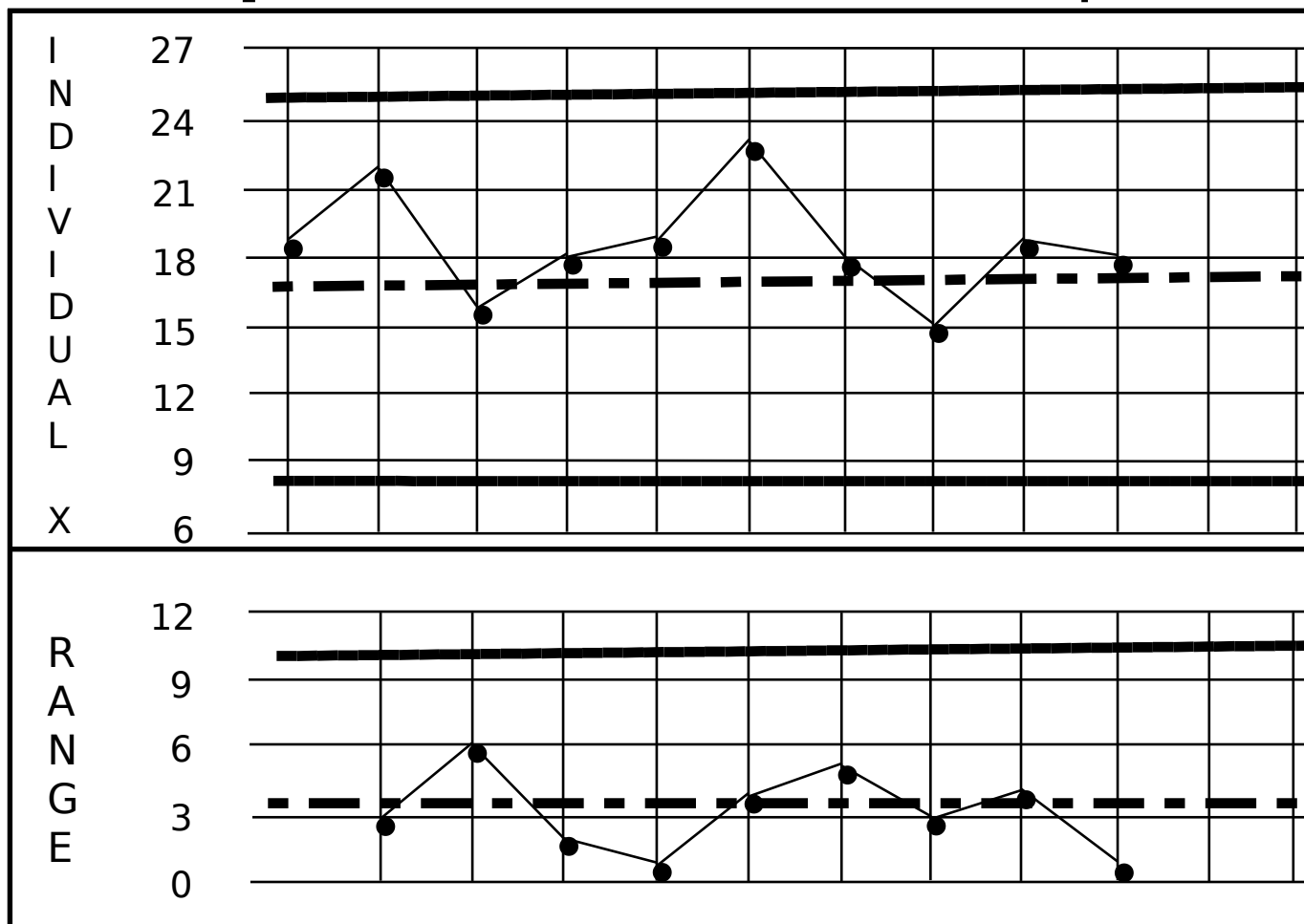
Enter the moving ranges

Constructing an XmR Chart

- Step 4** - Calculate average of data points
- Step 5** - Calculate average of moving ranges
- Step 6** - Calculate UCL and LCL for individual \bar{X}
- Step 7** - Calculate UCL for ranges
- Step 8** - Select scales and plot
- Step 9** - Document the chart

Constructing an XmR Chart

Step 8 - Select scales and plot



Constructing an XmR Chart

Step 10 - Check for *inflated* control limits

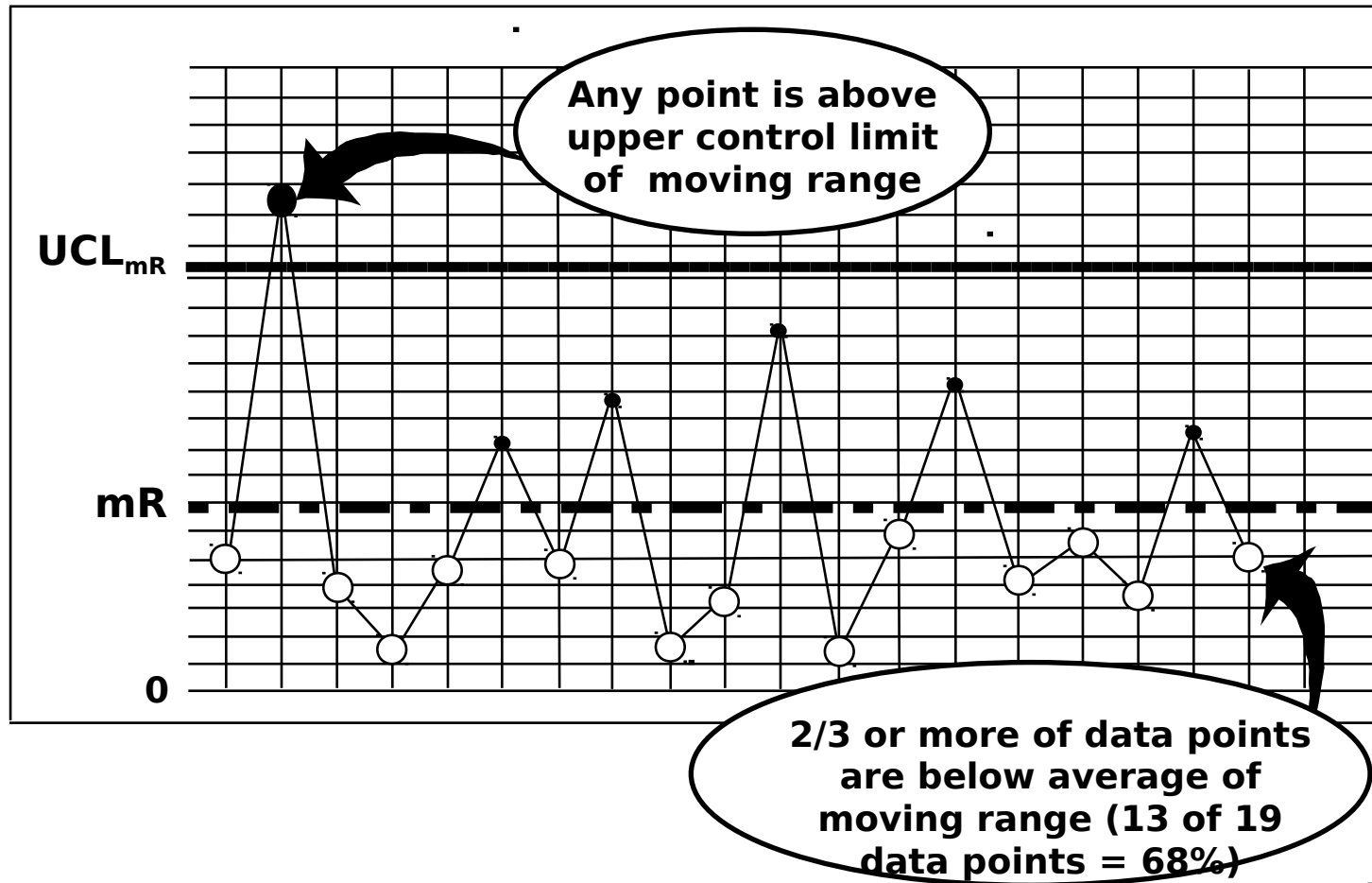
Step 11 - If inflated, calculate 3.144
times median mR

Step 12a - Do not recompute if 3.144
times median mR is greater than 2.66
times average of moving ranges

Step 12b - Otherwise, recompute all
control limits and centerlines

Constructing an XmR Chart

Step 10 - Check for inflated control limits



Step 12b - Constructing an XmR Chart

Upper Plot

$$UCL_x = \bar{X} + (3.144) (\text{Median Moving Range})$$

$$LCL_x = \bar{X} - (3.144) (\text{Median Moving Range})$$

$$\text{Centerline}_x = \bar{X}$$

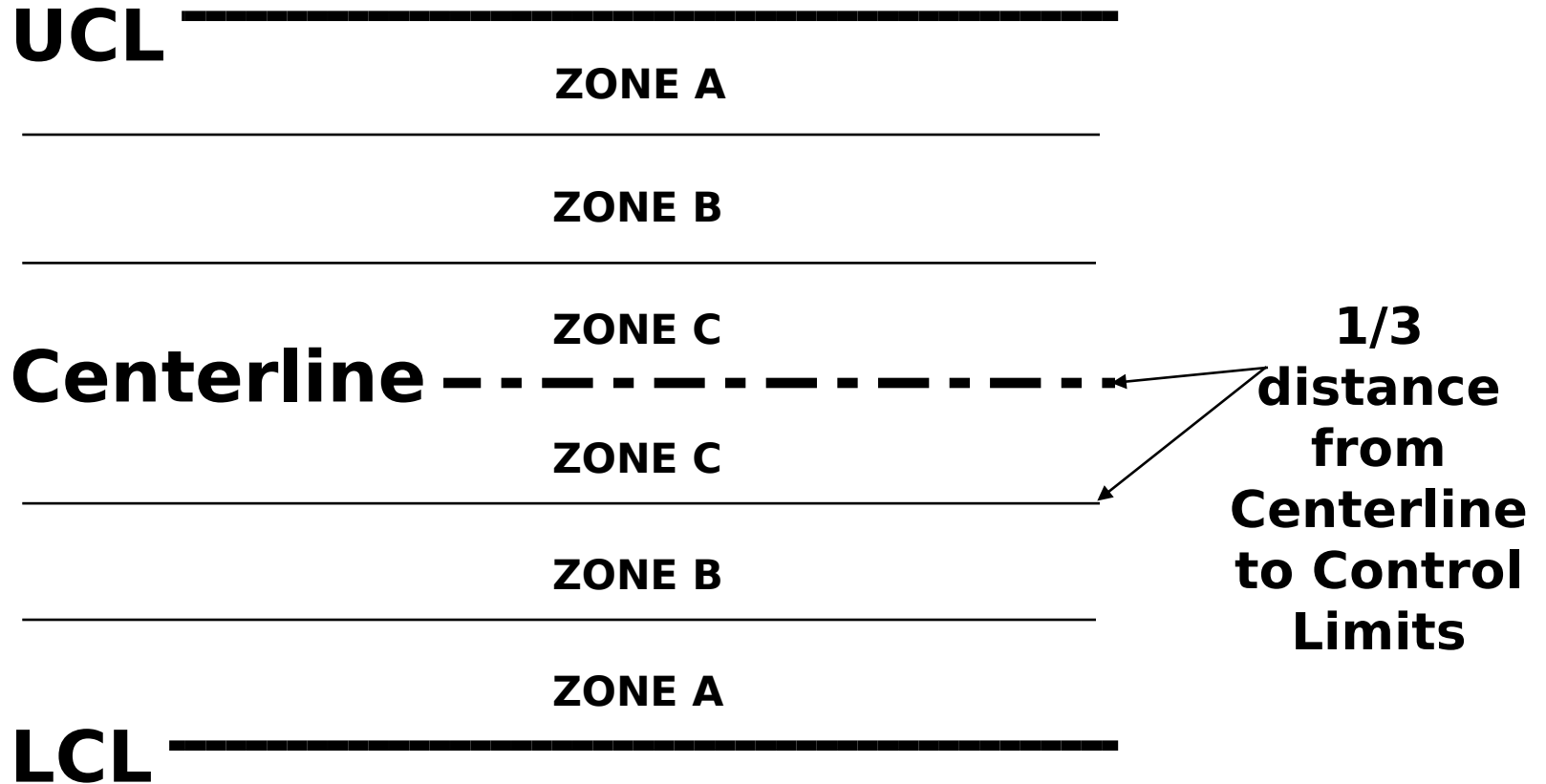
Lower Plot

$$UCL_{mR} = (3.865) (\text{Median Moving Range})$$

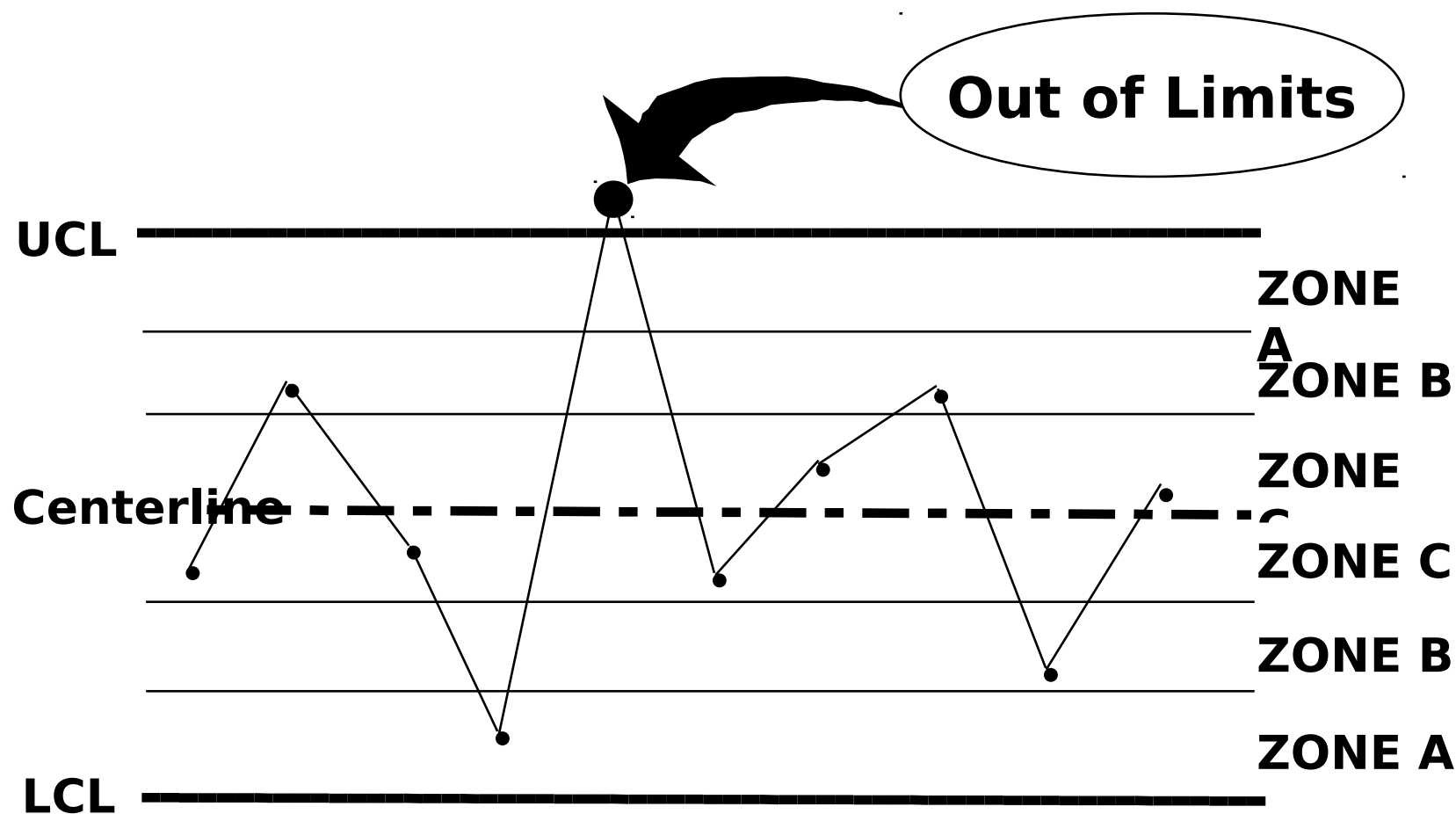
$$LCL_{mR} = \text{None}$$

$$\text{Centerline}_{mR} = \text{Median Moving Range}$$

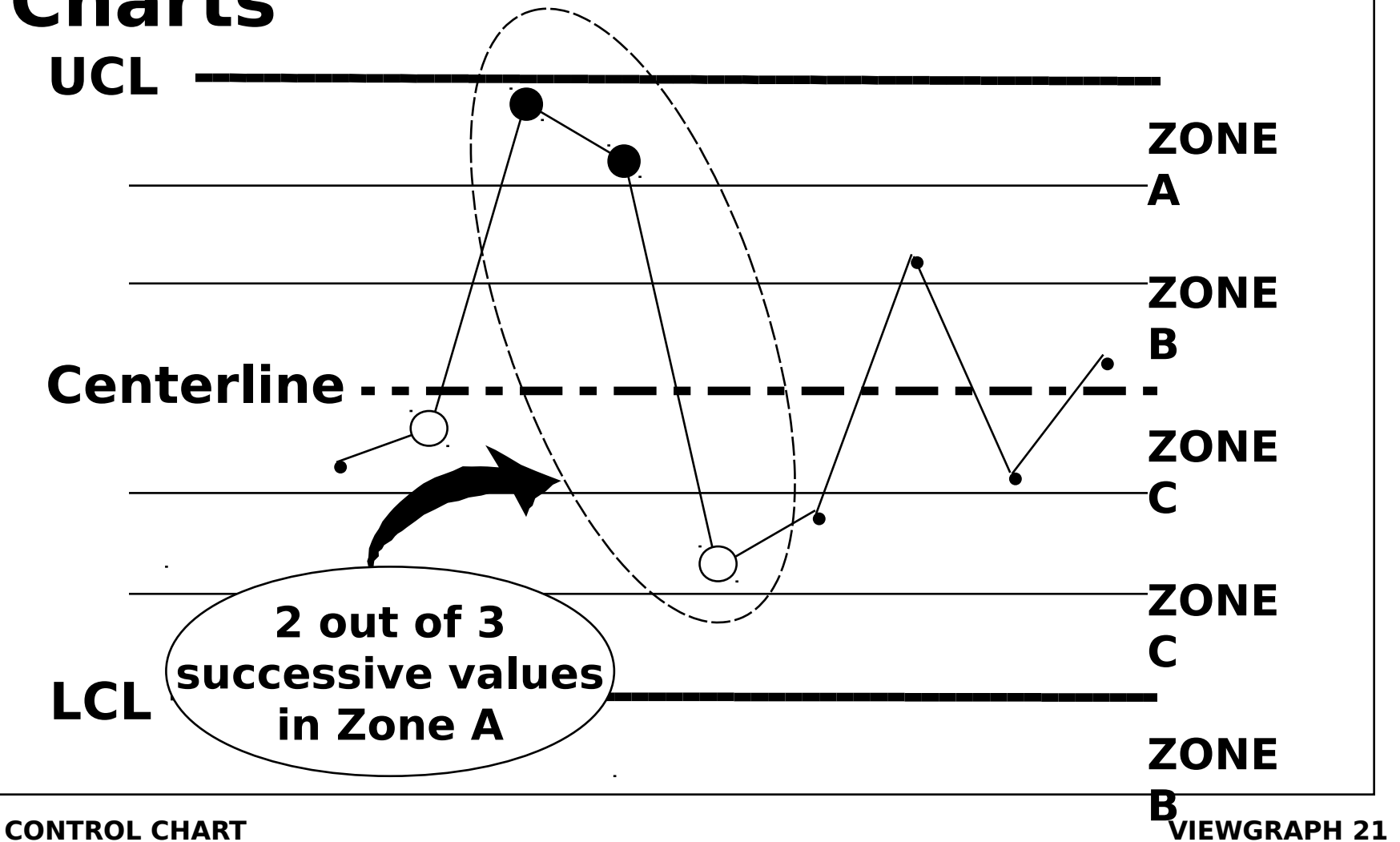
Control Chart Zones



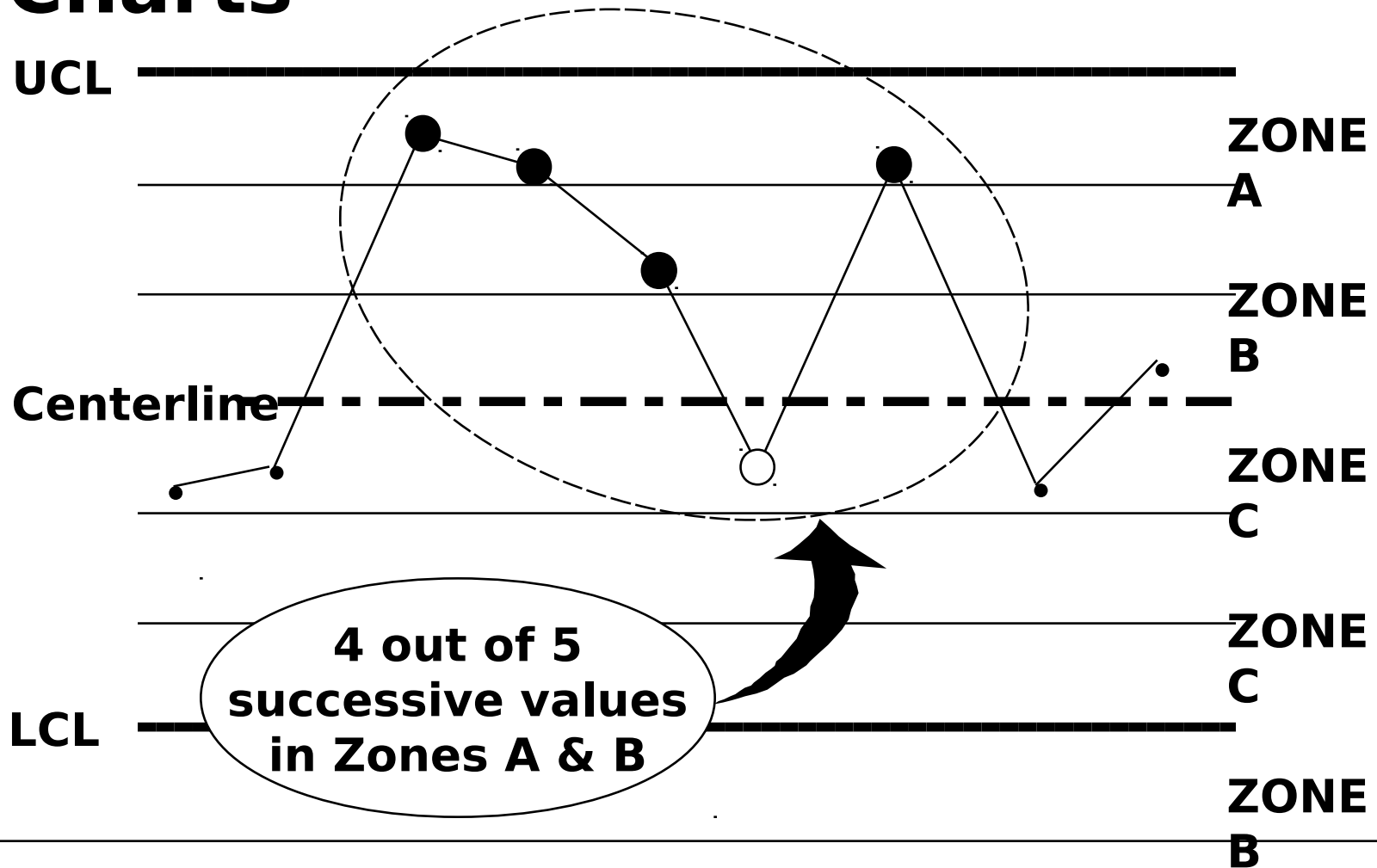
Rule 1 - Interpreting X-Bar & R Charts



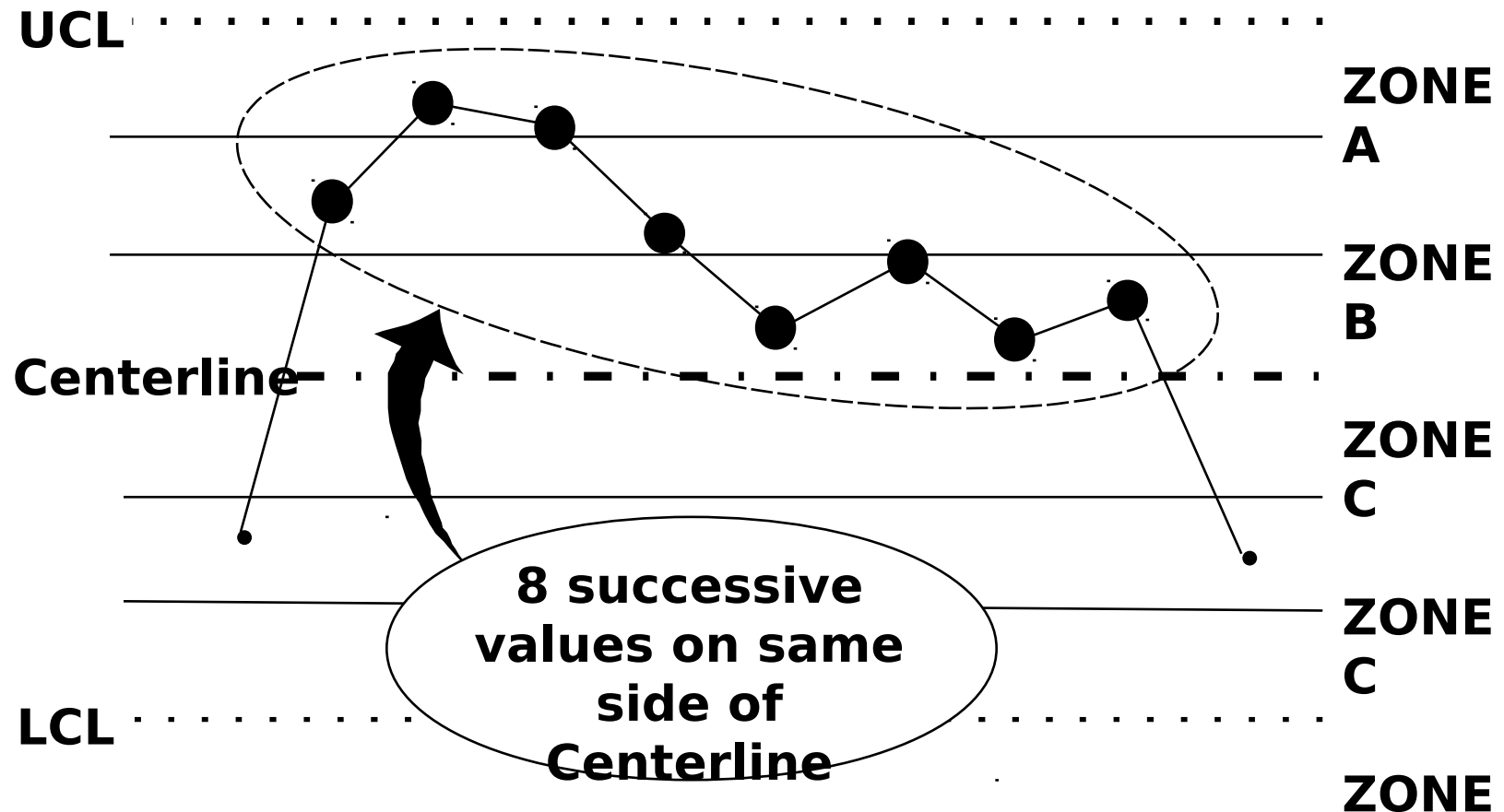
Rule 2 - Interpreting X-Bar & R Charts



Rule 3 - Interpreting X-Bar & R Charts



Rule 4 - Interpreting X-Bar & R Charts



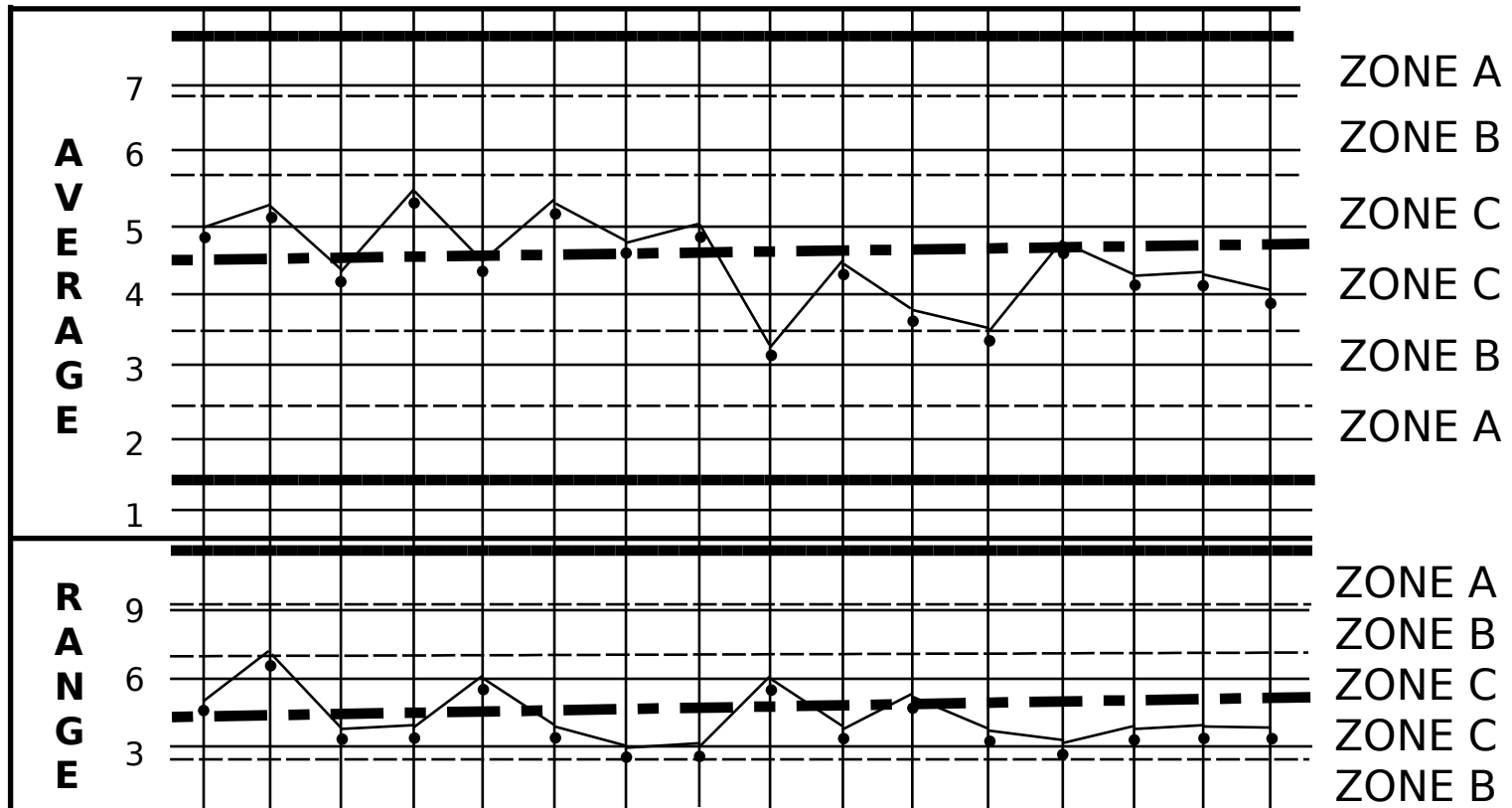
EXERCISE 1

Values of X-Bar and Ranges

	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	16
X_1	6	2	5	3	2	5	4	7	2	0 5	1 3	2 6	3 4	4 5	5 3	6
X_2	5	7	6	6	8	4	6	4	3	5	1	4	3	4	4	2
X_3	2	9	4	6	3	8	3	4	7	2	6	2	6	6	7	4
X_4	7	3	2	7	5	4	6	5	1	6	5	2	6	2	3	4
X-Bar	5.0	5.3	4.3	5. 5	4. 5	5. 3	4. 8	5. 0	3. 3	4. 5	3. 8	3.5	4.8	4.3	4.3	4.0
R	5	7	4	4	6	4	3	3	6	4	5	4	3	4	4	4

EXERCISE 1

X-Bar & R Control Chart



Note: Solid lines represent the grid used in this module; dashed lines separate zones.

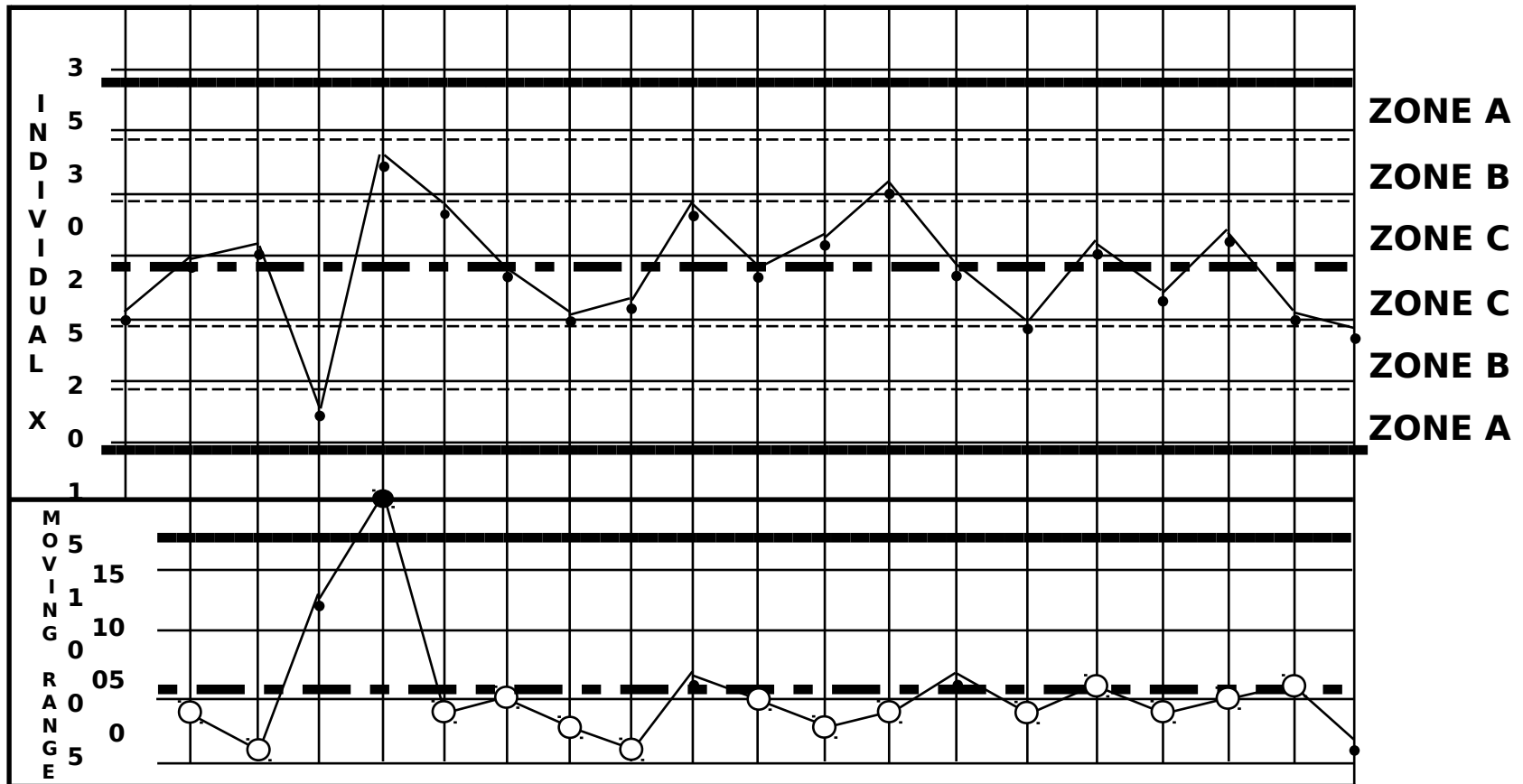
EXERCISE 2

Values of Moving Ranges

Date	1	2	3	4	5	6	7	8	9	1	11	12	13	14	15	16	17	18	19	2		
X Values	1	2	21	8	28	24	19	16	1	0	24	19	22	26	19	15	21	17	22	16	0	
mR	6	0	4	1	13	20	4	5	3	7	1	7	5	3	4	7	4	6	4	5	6	2

EXERCISE 2

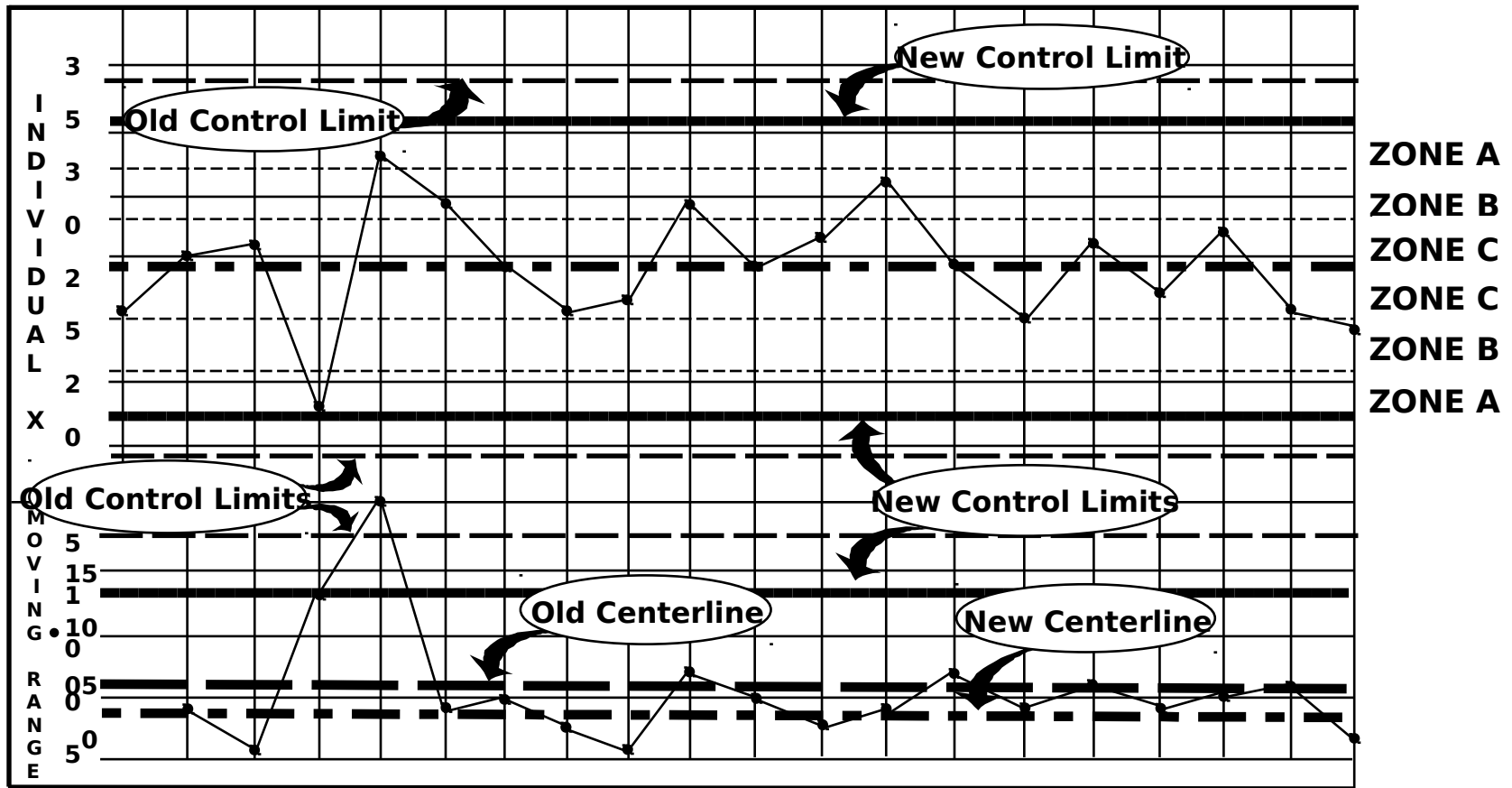
XmR Control Chart



Note: Solid lines represent the grid used in this module; dashed lines separate the zones in the upper plot.

EXERCISE 2

XmR Control Chart Revised for Inflated Limits



Note: Solid lines represent the grid used in this module; light dashed lines divide the zones in the upper plot.